IN SITU MASTCAM MULTISPECTRAL ANALYSIS OF CLAY-RICH SEDIMENTS IN THE GLEN TORRIDON REGION OF MT. SHARP, GALE CRATER, MARS. A. Rudolph[1], B. Horgan[1], K. Bennett[2], V. Fox[3], T. Seeger[4], M. Rice[4], J. R. Johnson[5], J. F. Bell III[6], S. Jacob[6], E. Rampe[7] [1]Purdue University (rudolph4@purdue.edu), [2]USGS Astrogeology Science Center, [3]California Institute of Technology, [4]Western Washington University, [5]JHU/Applied Physics Lab, [6]Arizona State University, [7]Johnson Space Center.

Introduction: The Curiosity rover arrived in the Glen Torridon (GT) region of Mt. Sharp on sol ~2300 [1]. This region was previously known as the "Clay-Bearing Unit" based on orbital detection of Fe/Mg-smectites [2, 3]. GT is part of the Murray formation, a unit at the base of Mt. Sharp that formed in a lacustrine environment when liquid water flowed on the surface of Mars [4, 5] and is a local topographic low between Vera Rubin ridge (VRR) and Greenheugh Pediment (Fig. 1). CheMin XRD analyses of drill samples in GT show the highest clay abundances detected to date [6]. However, the distribution of the clays and their relationship to bedrock properties like sedimentary facies is not well constrained. Understanding the distribution of clay minerals in GT is important for understanding the history of water-rock interactions and biosignature preservation potential in the region. In this study, we characterize the spectral diversity of GT using Mastcam multispectral data to constrain the distribution of clay minerals throughout the various facies investigated by MSL and their relationship to other alteration minerals.

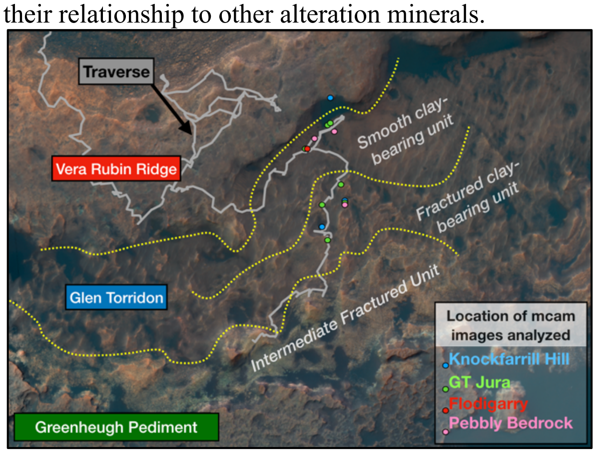

Figure 1: HiRISE color mosaic of GT and surroundings. Curiosity's traverse is the gray line. Boundaries between different orbitally-defined regions of GT are designated by the dotted yellow lines. Locations of mcam images analyzed and their corresponding morphologic groups are shown.

Methods: The Mastcam multispectral imager has 12 spectral channels in the VNIR range (445-1013 nm) and two cameras at different focal lengths (100mm and 34 mm) [7]. This spectral range is ideal for tracking variations in Fe-bearing materials from absorptions due to the $Fe^{2+/3+}$ charge transfer [8, 9] and crystal field effects in Fe-bearing silicates [10-12]. Images are calibrated using a target onboard the rover [7, 13]. Reflectance spectra for right and left camera images of manually defined Regions of Interest (ROI) were averaged and scaled based on the longest wavelength value of 1013 nm.

Here we investigate the spectral variability within GT (Fig. 1) using full-filter images acquired between sols 2361-2487 and search for trends within stratigraphic members and sedimentary facies (Fig. 2): the GT Jura member, which includes the Flodigarry facies, the Knockfarrill Hill member, and the Pebbly Bedrock facies which is present throughout GT. The GT Jura (Fig. 2a) is characterized by thinly laminated mudstones, a purple/gray/red hue, and sometimes a specular surface (Fig. 4c). The Flodigarry facies (Fig. 2c) is a subset of the GT Jura but presents as thin and thick interstratified layers. The Knockfarrill Hill member (Fig. 2b) is characterized by fractured bedrock and is often observed as a capping unit on buttes. From orbit, regions dominated by Knockfarrill Hill show a fractured morphology (Fig. 1). The Pebbly Bedrock facies (Fig. 2d) is composed of rounded pebbles of various colors and compositions, interpreted as an in situ lag deposit.

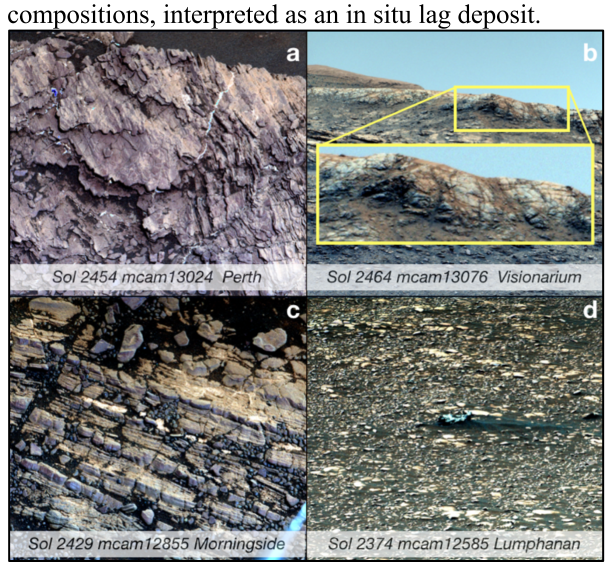

***Figure 2:** Morphologic groups present in GT shown with mcam R0 images. (a) GT Jura member (b) Fractured bedrock of the Knockfarrill Hill member, zoomed in yellow box highlights morphology (c) Flodigarry interstratified facies (d) Pebbly bedrock facies.*

Results: We identified three spectral classes within GT. The first spectral class (purple spectrum; Fig. 3a) exhibits a strong red slope at shorter wavelengths and a weak absorption centered at 860 nm. This is consistent with fine-grained red crystalline hematite and could be due to very small amounts of hematite (e.g., <2-3 wt.%) [14]. CheMin analyses show minor hematite (<3 wt. %) in all GT Jura and Knockfarrill Hill drill samples [15].

The second spectral class (pink spectrum; Fig. 3a) exhibits a weaker red slope at shorter wavelengths and has two prominent absorptions centered at 700 and 860 nm. The 700 nm band is potentially consistent with $Fe^{2+/3+}$-clays [9], coarse-grained gray hematite [16], or goethite or lepidocrocite [8]; however, the diminished red slope may be more consistent with gray hematite.

The third spectral class (green spectrum; Fig. 3a) has a strong red slope at shorter wavelengths and a weak absorption at ~900+ nm. This class could be consistent with several phases, but ferric smectites are plausible based on their strong orbital detections in this region [3]. This class was most frequently observed when ROIs are small (<10 pixels), which could suggest either that the distribution of this material is patchy, or that it is ubiquitous but is commonly obscured by patchy occurrences of spectrally dominant red hematite. Lab studies confirm that ferric smectites can affect the depth of the 860 nm band, but can easily be masked by red hematite [17].

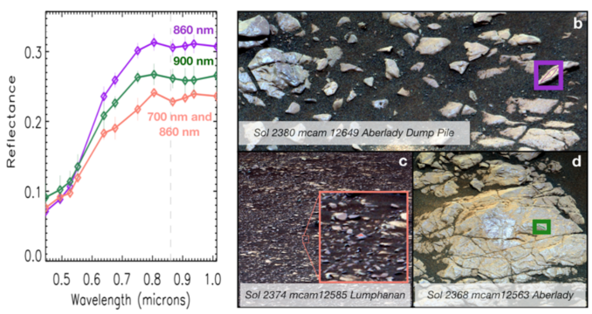

Figure 3: *(a) Representative spectra of three spectral classes: 860 nm absorption (purple), 700 nm and 860 nm absorption (pink), 900 nm absorption (green). Dashed gray line indicates 860 nm. (b-d) Locations of ROIs in mcam R0 images.*

No distinct pattern has been observed for where these spectral classes occur along Curiosity's traverse to date, and all three spectral classes are observed within both the Jura and Knockfarrill Hill members.

Spectral variations are also observed before and after drilling in the bedrock. The spectrum of the specular DRT (dust removal tool) surface before drilling (cyan spectrum, Fig. 4a) has a strong red slope at shorter wavelengths and an absorption centered at ~860 nm (spectral class 1). However, the outcrop surface is variable, and smaller nearby ROIs in the pre-drill image show regions that exhibit spectral class 3 characteristics. The drill tailing spectrum (green spectrum, Fig. 4a) has a strong red slope at shorter wavelengths and an absorption shifted to a longer wavelength (spectral class 3). Spectral variation from outcrop surface and from before and after drilling suggests that compositional variations are present between the surface and the subsurface.

Discussion: The ~900+ nm absorption bands are consistent with Fe/Mg phyllosilicates detected throughout GT by CheMin [6,15] as well as in orbital spectra [3]. However, these signatures are only present in small patches, and weak red crystalline hematite signatures still spectrally dominate bedrock outcrops, consistent with the small amount of hematite detected by CheMin [14, 15]. We hypothesize that clay minerals are approximately uniformly distributed throughout the GT members, but the distribution and the grain size of hematite is spatially variable (e.g. spectral class 2 could be consistent with coarse-grained hematite).

GT exhibits spectral similarities to lower stratigraphic members. The Sutton Island member below VRR often exhibits ~900+ nm bands consistent with Fe/Mg-clays similar to but stronger than in GT, and rare hematite bands [18]. These clays may have formed in the near-shore environment in which this member was deposited [19]. 700 and 860 nm bands consistent with gray/red hematite and similar to GT were observed in the VRR Jura member [20], while possible clay signatures were rare and CheMin clay abundances were low [21]. Red and gray hematite on VRR may have formed during alteration by early and late diagenetic fluids [20].

We hypothesize that weak clay and patchy hematite signatures in the GT Jura and Knockfarrill Hill members may be consistent with an interplay between early alteration and subsequent diagenetic processes. The ubiquity of clay minerals in GT suggests that they formed in the early surface environment or during early diagenetic processes prior to lithification. In contrast, patchy hematite could have formed due to subsequent diagenetic processes, where clay minerals might have inhibited fluid flow, leading to patchy diagenetic minerals.

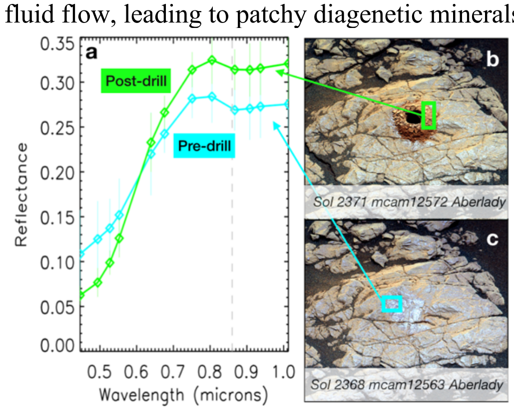

Figure 4: *Comparison of spectra before and after drilling. (a) Cyan is pre-drill DRT, green is post-drill, gray dashed line at 860 nm. (b-c) Locations of ROIs in R0 images.*

References: [1] Fox V. et al. (2019) *LPSC L,* #2826. [2] Milliken R. E. et al. (2010) *GRL.,* 37. [3] Fraeman A. et al. (2016) *JGR,* 121. [4] Grotzinger J. et al. (2014) *Science*, 343. [5] Grotzinger J. et al. (2015) *Science*, 350. [6] Bristow T. F. et al. (2019) *9th Mars,* #6390. [7] Wellington D. et al. (2017) *Am. Min.*, 102. [8] Morris R. et al. (1985) *JGR.,* 90. [9] Sherman D. M. (1990) *ACS Symp. Series*, Chp. 15. [10] Adams J. (1968) *Science*, 159. [11] Cloutis E. & Gaffey M. (1991) *Earth, Moon, Plan.*, 53. [12] Horgan B. et al. (2014) *Icarus*, 234. [13] Bell III J. et al. (2017) *E&SS.,* 4. [14] Morris R. et al. (1989) *JGR,* 94. [15] Thorpe et al., this volume. [16] Christensen P. et al. (2000) *JGR,* 105. [17] Jacob S. et al., this volume. [18] Haber et al., this volume. [19] Fedo et al. (2019) *Mars 9* #6308. [20] Horgan B. et al. (2019), LPSC 50, #1424. [21] Rampe E. et al. (submitted) *JGR*.